THE COST-EFFECTIVENESS OF MILITARY TRAINING

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ABSTRACT

The use of flight simulators, computer-based instruction and maintenance training simulators for training is evaluated on the basis of their effectiveness and cost. Flight simulators are cost-effective, compared to the use of aircraft, for training; so are maintenance training simulators compared to actual equipment trainers. Computer-based instruction is as effective as conventional instruction; comparable cost data are not yet available, so one cannot say whether it is also cost-effective. These three methods of training are not more effective than the methods to which they were compared, except for small improvements in a few cases. It is possible they could be made more effective if cost savings were not a major goal, but this remains to be determined. The goal of analyses of training should be an ability to perform trade-offs of the effectiveness and costs of new methods of training, but no such trade-offs have yet been made.

PURPOSE

The purpose of this paper is to evaluate both the cost and effectiveness of military training in three areas where relevant data are available: flight simulators, computer-based instruction, and maintenance training simulators.

THE MAGNITUDE OF MILITARY TRAINING

Military training makes a large and continuing demand on resources allocated to the military services. For example, the time spent by students in individual training at designated schools plus that of the instructors needed at those schools accounts for about one-fourth of all the man-years (both military and civilian) available to the Department of Defense (Figure 1). About 20 percent of all military personnel are in schools at all times, either as students or instructors. Most (about 76 percent) of this effort simply provides initial training to new personnel entering military service for the first time.

Individual training at military schools will cost $12.8 billion in Fiscal Year 1983. The types of training vary widely by number of students and cost per student, as shown in Figure 2. This information can help tell us where improvement in training could have large impact. For example, specialized skill training involves the largest number of students and costs more than any other type of individual training. Undergraduate flight training, for pilots and other aircrew, has the smallest number of students, but it costs much more per student than any other type of individual training.

It may be noted, in passing, that student needs additional training after he leaves school. This is known, variously, as on-the-job training, advanced flight training, crew training, and field exercises. None of the costs of additional training needed after leaving a school is included in the data shown in Figure 2.

Finally, it may help to know that the cost of individual training at school is nontrivial when compared to other, readily available, costs in the annual military budget. As shown shown in Figure 3, individual training at school costs about half (or more) of what is spent for intelligence and communications, the strategic forces, or for all research, development, test, and evaluation; and roughly 15 percent of how much is spent for procurement or operation and maintenance. Military training is a major component of the military budget. Operational readiness depends on effective training. It is possible to realize the high levels of performance built into our advanced weapon and support systems only if these systems are maintained and operated according to their design specifications, and this also depends on effective training. Thus, it is almost mandatory to have effective training; improvements in our current methods of training are likely to have useful and significant payoffs.

There is, generally, more than one way of training most skills, e.g., group lectures, individual coaching, use of simulators, and so on. The first question which must be answered--whether it concerns new or current technology--is, "Is it any good? Does it train as well as, or perhaps, better than some other way we could use?" This is the issue of effectiveness of training. But the effectiveness of training cannot be addressed meaningfully without also considering its

	MAN-YEARS (000)	
	MILITARY	CIVILIAN
STUDENTS	255	—
INSTRUCTORS	133	59
TOTAL	388	59
DoD END-STRENGTH	2148	1035
PERCENT IN TRAINING	18%	6%

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FIGURE 1. The Amount of Time Spent by Students and Instructors in Individual Training at Military Schools, FY 1983 (Source: Military Manpower Training Report for FY 1983; Weinberger 1982).

TYPE OF INITIAL TRAINING	NUMBER OF STUDENTS (INPUT, 000)	COST	APPROXIMATE COST/STUDENT
RECRUIT	363	$ 871 M	$ 2 K
ONE-STATION UNIT TRAINING (ARMY)	119	332	3
OFFICER ACQUISITION	20	376	19
SPECIALIZED SKILL	1,347	2,883	2
UNDERGRADUATE FLIGHT	18	1,825	100
PROFESSIONAL DEVELOPMENT EDUCATION	35	427	12
MEDICAL	—	431	
SUPPORT, MGMT, TRAVEL, PAY	—	5,626	
TOTAL		$12,771	

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FIGURE 2. Number of Students and Costs of Various Types of Individual Training at Military Schools, FY 1983 (Source: Military Manpower Training Report for FY 1983).

ITEM	COST (Billions)	INDIVIDUAL SCHOOL TRAINING, AS PERCENT OF OTHER COSTS
INDIVIDUAL SCHOOL TRAINING	$12.8 B	
INTELLIGENCE AND COMMUNICATIONS	18.0	71%
STRATEGIC FORCES	23.1	55
RDT&E	24.3	53
OPERATION AND MAINTENANCE	70.4	18
PROCUREMENT	89.6	14

6-3-83-2

FIGURE 3. A Comparison of the Budgets for Individual School Training and Other Major Military Expenditures, FY 1983 (Source: Weinberger 1982).

cost. Almost any method of training could be made effective if enough money for equipment and instructors and long training time for students students were made available. Therefore, if two methods of training are equally effective, we should select the one that costs less. If two methods of training cost about the same, we should select the one that is more effective. If a new method of training is more effective and costs less, the choice is easy and obvious, but such opportunities are rare.

We will consider next comparisons of the effectiveness and cost of three types of training: flight simulators and aircraft, computer-based instruction and conventional instruction, and maintenance training simulators and actual equipment trainers. This will be followed by a discussion of what the results mean for future evaluations of training.

FLIGHT SIMULATORS(1)

The extent to which flight simulators should be used in flight training is a major concern to all military services. The key questions are obvious:

- do flight simulators really train pilots
- do the skills learned in flight simulators transfer readily to aircraft
- are flight simulators worth what they cost

The last question cannot be ignored since the cost of some modern flight simulators, when equipped with advanced visual systems and motion bases, approaches the cost of aircraft.

The procurement of new simulators, including major improvements to those acquired previously, has averaged about $275 million per year for the last eight years (Figure 4). It costs about $3.6 billion per year for fuel and supplies needed to operate military aircraft. About 7,600 new pilots will be qualified in fiscal year 1983 at a cost of about $1.8 billion.

How much does it cost per hour to operate simulators and aircraft? Figure 5 shows comparable operating cost data for 42 pairs of flight simulators and aircraft for fiscal years 1980 and 1981. Variable Operating Costs, as shown here, are for fuel, oil, and spare parts consumed as a function of use; the costs of pay and amortization are not included in these amounts. The median ratio of simulator/aircraft operating costs is 0.08; it was 0.12 in fiscal years 1975 and 1976.

The fact that flight simulators cost less to operate than aircraft is a useful but not conclusive finding unless we also know how well they may be used to train pilots. The effectiveness of a flight simulator may be evaluated by determining how much time, if any, it saves in training pilots to perform specific tasks in an airplane, compared to the amount of time required for such training only in the airplane. The same level of performance in aircraft is required in both cases. It has long been known that pilots can perform in the air, more or less well, tasks learned in flight simulators. The real question is how good

(1)This information is based on Orlansky and String, 1977.

PROCUREMENT OF SIMULATORS	$0.275 B/YR	FY 75-82
ALL FLYING COSTS	$3.6 B/YR	FY 1981
UNDERGRADUATE PILOT TRAINING		FY 1983
INPUT	9337	
OUTPUT	7603	
LOAD	5581 MAN-YEARS	
COST	$1.8 B	

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FIGURE 4. Major Costs Associated with All Flight Training.

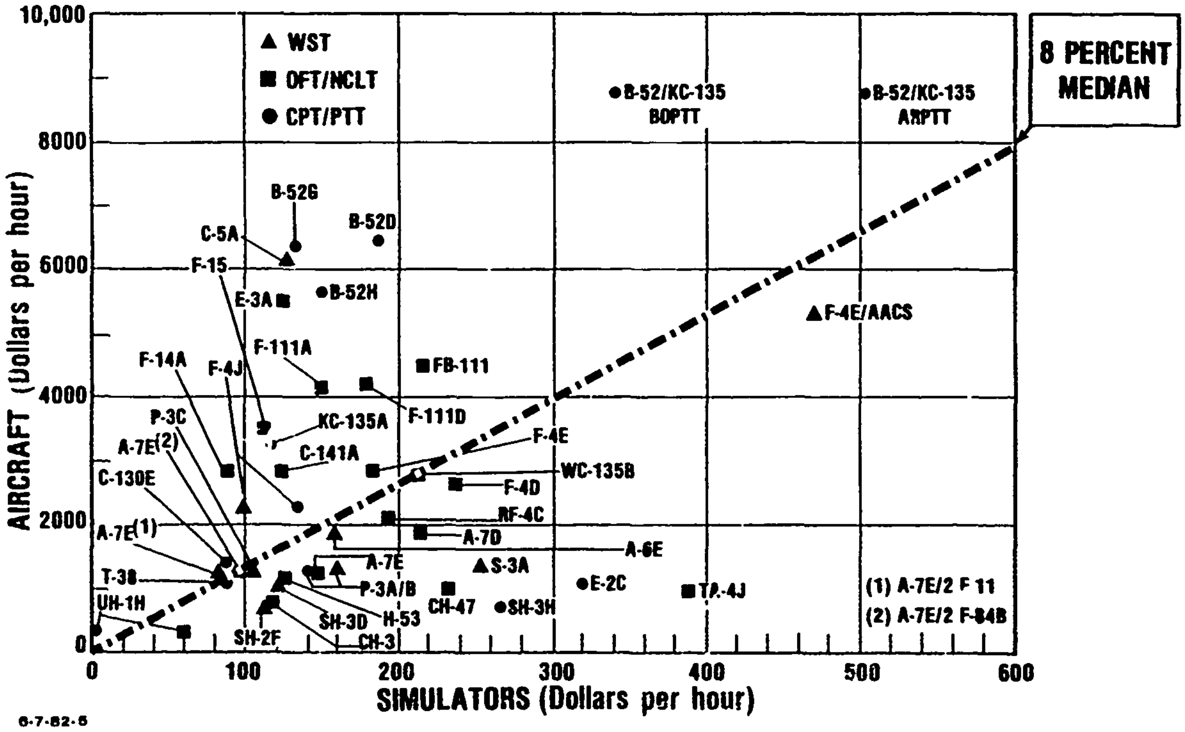

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FIGURE 5. Variable Operating Costs Per Hour for 42 Flight Simulators and Aircraft, FY 1980 and FY 1981.

is this training. An index, called the Transfer Effectiveness Ratio (TER), shows the amount of flight time saved as a function of the amount of time spent in the simulator (Figure 6).

Transfer effectiveness ratios from 34 different studies of flight training (e.g., basic contact flight, instrument flight, ASW maneuvers, multi-engine transition) are shown in Figure 7. The TERs range in value from -0.4 to 1.9, with a median value of 0.48. Using the median value, the data show that pilots trained in simulators needed less time in aircraft to perform acceptably than pilots trained only in aircraft; the amount of flight time saved was about one-half of the time spent in the simulator. There is a wide range in these TERs; clearly, these flight simulators were not equally effective in saving flight time in all cases, and it seems important to identify the factors that make for efficient and inefficient uses of simulators.

Since flight simulators save about 50 percent of the time needed by pilots to train in aircraft and cost only 8 percent as much to use (median values in both cases), it is clear that flight simulators are cost-effective, compared to the use of aircraft alone for training. The amount of such savings, after providing for the cost of these using simulators, is shown for three cases in Figure 8; the savings were large enough to amortize the procurement cost of flight simulators within two years or less.

COMPUTER-BASED INSTRUCTION[2]

The question addressed here is whether instruction that is supported by the use of computers is cost-effective compared to conventional, classroom instruction. Conventional instruction is based largely on lecture, discussion, and some amount of individual coaching. Its salient features are group-pacing, and some amount of individual attention. Conventional instruction was compared to two new methods of instruction, both using computers, that have been developed since about 1960. The first method, Computer-Assisted Instruction (CAI), involves placing all the instructional material in the computer. It provides lessons to the student by means of a cathode ray tube; the student may respond by such means as a keyboard or by touching the screen. The computer guides the student, corrects him as needed, and provides new or explanatory material to suit his method of learning; the computer maintains student progress records and can provide a variety of administrative information needed to operate a course and/or school. In the second method, Computer-Managed Instruction (CMI), the student receives his instruction away from the computer, i.e., in a learning carrel or at a laboratory bench. However, he takes a test on some amount of course material, typically after about one hour's worth of instruction. The computer scores the test, interprets the results for the student, and directs him to his next lesson or to repeat the last one. The computer performs a similar evaluation and guidance function in both cases, except that it is based on individual responses in CAI and comes only after tests in CMI. The salient features of CAI and CMI are that each student proceeds at his own rate of learning ("self-paced" instruction) and receives frequent feedback on his progress. This may be contrasted with group-paced instruction where tests are spaced further in time (daily, weekly or monthly) and where all students must proceed at the same pace despite known differences in rate and/or style of learning.

Computer-assisted and computer-managed instruction are significant alternatives to conventional instruction primarily in specialized skill training. About 1.4 million students are trained in various special skills at a cost of about $2.9 billion each year (Figure 9). Most (76 percent) of these students are "new accessions", i.e., personnel recently admitted to the military services who are being trained for their first military assignment. There is a continuous need to train replacements for those who now leave the military services after relatively short careers.

CAI and CMI may have many advantages, but the fundamental question must be how effective they are, compared to conventional instruction, in instructing students. This issue has been addressed in 48 studies, conducted from 1968 to 1979, that are summarized in Figure 10. Using grades in end-of-course tests as a measure, these studies compared achievement of students in the same courses when taught by conventional instruction or by CAI or CMI. Six different CAI systems and two different CMI systems were compared in a wide variety of technical training courses. Student achievement with CAI or CMI is shown in the figure either as "inferior", "same", or "superior" to achievement with conventional instruction for the same course; the result of each study is represented by a dot placed in the appropriate column. The figure shows clearly that student achievement at school with CAI or CMI is about the same as, or in some cases superior to, that with conventional instruction. The amount of superior achievement (i.e., higher scores) is not large.

In conventional instruction, the rate at which new information is presented is based on about how much the average student can absorb. The entire class proceeds at the same rate (called "group-pacing" or "lock-step" instruction); this pace necessarily holds back students who can learn at a faster rate. With CAI and CMI, each student proceeds at his own rate. Thus, we should expect that students instructed by CAI or CMI should complete their courses in less time, on the average, than those taught by

[2]Based on Orlansky and String, 1979.

$$TER = \frac{A - A_s}{S}$$

A = AIRCRAFT TIME, WITHOUT SIMULATOR

A_s = AIRCRAFT TIME, AFTER SIMULATOR

S = SIMULATOR TIME

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FIGURE 6. Transfer Effectiveness Ratio (TER) (Source: Roscoe 1971, 1972).

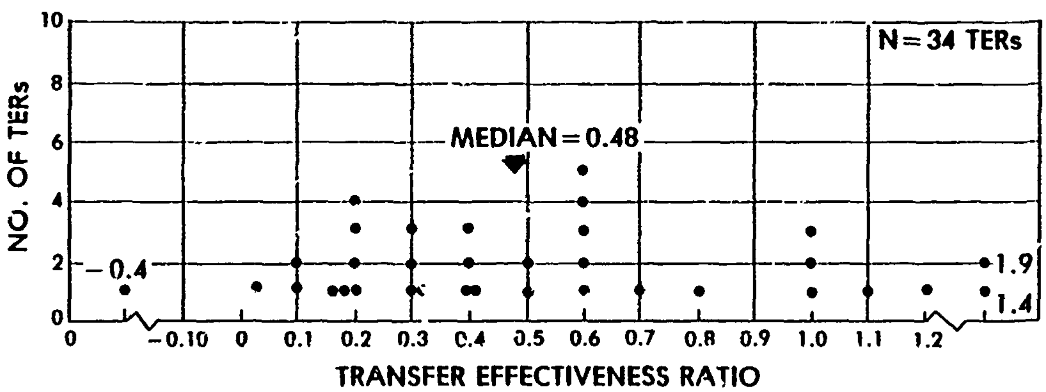

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FIGURE 7. Transfer Effectiveness Ratios for Various Types of Flight Training, Based on 22 Studies Performed 1967-1977.

SIMULATOR	PROCUREMENT COST	SAVINGS PER YEAR	PROCUREMENT COST/ SAVINGS PER YEAR
COAST GUARD, HH-52A HH-3F	$ 3.1 M	$ 1.5 M	2.1 YEARS
NAVY, P-3C	4.2 M	2.5 M	1.7 YEARS
AIRLINE	17.5 M	25.3 M	8.3 MONTHS

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FIGURE 8. Amortization of Flight Simulators.

SPECIALIZED SKILL TRAINING FY 1983

1,350,000 STUDENTS

76 PERCENT NEW ACCESSIONS

$2.883 BILLIONS

6-3-82-4

FIGURE 9. The Magnitude of Specialized Skill Training, FY 1983.

FIGURE 10. Student Achievement at School: CAI and CMI Compared to Conventional Instruction.

METHOD OF INSTRUCTION	SYSTEM	SERVICE	LOCATION	STUDENT ACHIEVEMENT AT SCHOOL (compared to conventional instruction)			TYPE OF TRAINING
				INFERIOR	SAME	SUPERIOR	
CAI	IBM 1500	A	SIGNAL C&S		• • • •	• •	ELECTRONICS
		N	SAN DIEGO			• • • • •	ELECTRICITY
	PLATO IV	A	ABERDEEN		• • •		MACHINIST
		N	SAN DIEGO		• •	• • • •	ELECTRONICS
		N	SAN DIEGO		• •		RECIPE CONVERSION
		N	NORTH ISLAND			•	A/C PANEL OPERATOR
		AF	SHEPPARD		• •	• •	MEDICAL ASSISTANT
		AF	CHANUTE		• • • •		VEHICLE REPAIR
	LTS-3	AF	KEESLER		• •	•	ELECTRONICS
		AF	KEESLER		•		WEATHER
	TICCIT	N	NORTH ISLAND		•		TACTICAL CO-ORD. (S-3A)
	IDIOM	N	DAM NECK	•	•		FIRE CONTROL TECHNICIAN
	PLATO IV	N	DAM NECK		• •		FIRE CONTROL TECHNICIAN
				TOTAL 1	24	15	
CMI	NAVY CMI	N	MEMPHIS		• •		AVIATION FAMILIARIZATION
		N	MEMPHIS		• •		AV. MECH. FUNDAMENTALS
	AIS	AF	LOWRY		•		INVENTORY MGMT.
		AF	LOWRY		•		MATERIEL FACILITIES
		AF	LOWRY		•		PREC. MEASURING EQPT.
		AF	LOWRY		•		WEAPONS MECHANIC
				TOTAL 0	8	0	

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conventional instruction. Data on student time savings, drawn from the studies on student achievement reported above, are shown in Figure 11. The average amount of student time saved by CAI or CMI, compared to conventional instruction, shows a very wide range--from -30 percent to as much as 85 percent (i.e., in a few cases, CAI or CMI took more time). The median value is a time saving of about 30 percent.

There are few data that compare the costs of CAI or CMI and conventional instruction for the same course, and these comparisons tend to be incomplete. Data on student time savings appear to be reliable; however, many other costs must also be considered, e.g., for program development (hardware, course materials, programming), the delivery of instruction (instructors, support, supplies, repairs), and student pay and allowances. No such comparison was made in any of the studies reported above that contained data on student achievement and time saved.

It is often suggested that computer-based instruction is cost-effective because the cost of computers has declined dramatically in the last few years. This true statement can be misleading because it overlooks the fact that the costs of developing software and course materials (both labor-intensive) have been increasing over the same time period. Some studies on the cost-effectiveness of the PLATO IV system (at Aberdeen Proving Ground, North Island, and Chanute Air Force Base) and the Air Force Advanced Instructional System (at Lowry Air Force Base) were conducted during the period of 1975 to 1978. The general findings were that, compared to conventional instruction, these systems were, at that time, either marginally cost-effective or not cost-effective. None of these studies can be represented as conclusive or used as a basis for judgment at the present time because of the large improvements in computer technology that have taken place since they were completed.

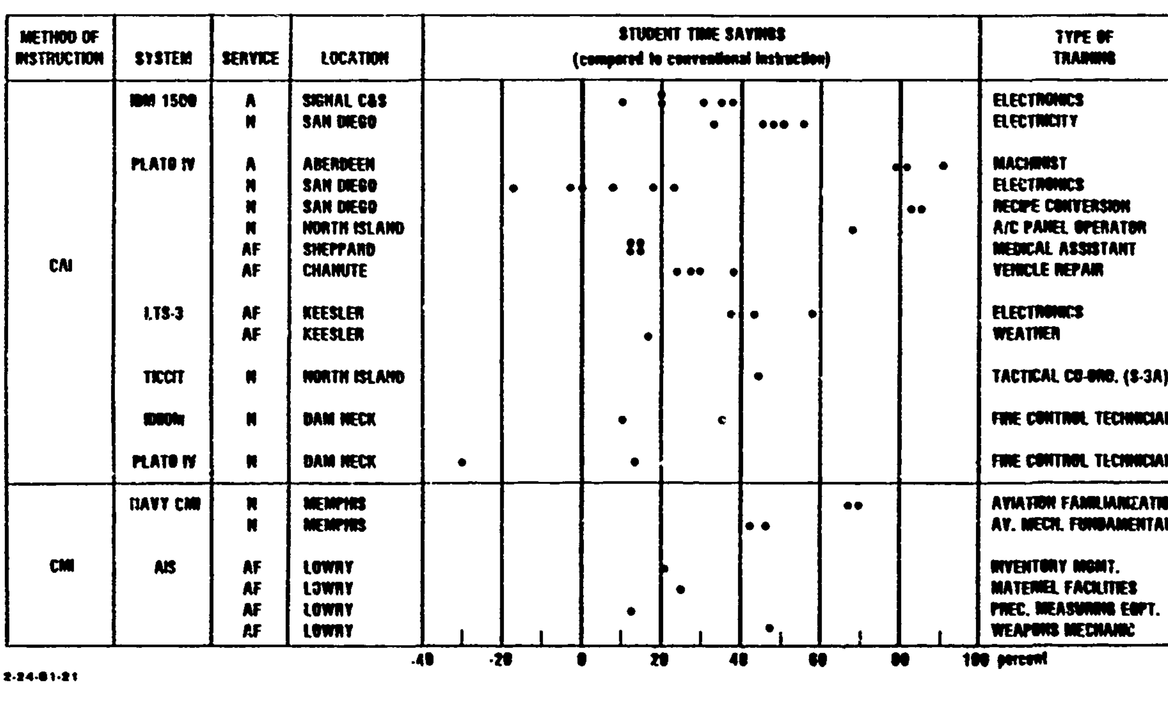
Thus, it can be said that computer-based instruction is as effective as conventional instruction on the basis of student achievement at school, and that it saves student time needed to complete various courses. However, comparisons of the total costs of these methods methods of instruction, using current data and technology, remain to be accomplished.

MAINTENANCE TRAINING SIMULATORS(3)

Operational equipment is used often at schools to train technicians how to perform routine maintenance, diagnose malfunctions, and replace faulty parts. It seems reasonable to do this because trainees will have to maintain the same equipment later in the field. In addition, actual equipment needed for training can be acquired readily by buying an additional unit off the production line. Unfortunately, the use of actual equipment is not

(3)Based on Orlansky and String, 1981.

FIGURE 11. Amount of Student Time Saved by CAI and CMI, Compared to Conventional Instruction.



necessarily the most effective way to train new technicians. The instructor must be able to insert "faulty" parts in order to demonstrate fault finding procedures. Apart from the fact that it takes some time to prepare each lesson on faults, there will be, at best, a limited repertoire of faults that can be illustrated. Wear and tear on "failed" parts makes them easy to detect with little regard to the particular malfunction that is being demonstrated. Major faults or casualties are not introduced in large systems where the investment cost is high for fear of damaging the trainer. For the same reason, only the instructor makes calibrational or adjustment changes. Cascading casualties are difficult if not impossible to induce into real equipment. Further, it is dangerous to use some operational equipment in a school because of high voltages or pressures; operational equipment may break down at school because of abuse by students, not be ready when needed for training, and may entail high maintenance costs.

Most of these limitations may be overcome by using maintenance training simulators, rather than actual equipment, to train technicians. Such simulators always incorporate some type of computer-based control. Thus, it is easy to provide a large number of malfunctions (e.g., combinations of instrument readings and non-responsive controls) that an instructor can easily and quickly select. Simulators can be made both safe for use and resistant to abuse by students. Above all, being computer-based, such simulators can record student performance and provide knowledge of results that otherwise would require fulltime observation of every student by a qualified instructor. The use of maintenance simulators is increasing gradually, primarily in aircraft applications (Figure 12).

The effectiveness of maintenance simulators and of actual equipment trainers has been been compared in about 15 studies conducted from 1967 to 1980 (Figure 13); five different types of simulators were evaluated. The findings are as follows:

1. Simulators were as effective as actual equipment trainers.
2. Simulators saved some student time.
3. Students favored simulators more than instructors did.

Relatively complete data on the acquisition costs of maintenance simulators and of comparable actual equipment trainers are available in 11 cases. Since these maintenance simulators are prototype equipments, they include costs both for development and for fabricating a single unit. Therefore, two estimates were developed for the acquisition cost of a maintenance simulator: a high estimate that includes the cost of research and development plus the cost of fabricating one production unit; a low estimate that includes only the cost of fabricating one production unit. The cost of an actual equipment trainer is the recurring production cost plus the cost of modifying that unit to make it useful at school.

The acquisition cost of maintenance simulators is between 0.20 to 0.60 as much as that for comparable actual equipment trainers, depending on the method used to estimate the cost of the simulator (Figure 14). The lower ratio is probably the more meaningful comparison because it excludes the costs of research and development both for simulators and actual actual equipment trainers. However, a comparison limited only to acquisition costs overlooks the long term costs of using simulators and actual equipment trainers.

Only one complete cost-effectiveness evaluation of a maintenance simulator and its comparable actual equipment trainer has been found. This was a 15-year life-cycle cost comparison of the Air Force 6883 Avionics Test Bench 3-Dimensional Simulator for the F-111 aircraft and the actual equipment trainer (Cicchinelli, Harmon, Keller and Kottenstette, 1980). The study finds that both were equally effective, as measured by student performance at school and by supervisors' ratings of performance of course graduates later on the job. Savings due to use of the simulators are due primarily to lower operating costs over the period of interest. With these savings, the acquisition cost of the simulator can be amortized within four years (Figure 15).

DISCUSSION

The findings of these studies on the cost-effectiveness of selected types of military training are summarized in Figure 16; the values are rounded off. The overall interpretation must be that innovations to training in these areas are as effective as the methods and/or equipments to which they were compared. Where cost data are available, the innovations cost less to procure and use than the systems they can replace. Thus, research and development on training has led to innovations that are cost-effective. This overall conclusion must be qualified because some of the data are incomplete, as discussed next. Credible data that compare the complete costs of computer-based instruction and conventional instruction have not yet been developed. This applies also to the operating and life cycle costs of maintenance simulators and of actual equipment trainers. There is a need not only for more complete cost data but for data that can be used to identify the high cost elements (i.e., cost-drivers) in such training systems; such data are needed also to develop cost-estimating relationships for estimating the probable costs of new training systems.

It is important to note that the effectiveness of computer-based instruction and of maintenance simulation has been demonstrated only on the basis of student achievement at school. Such data do not tell us how well these students perform on the job, and job perform-

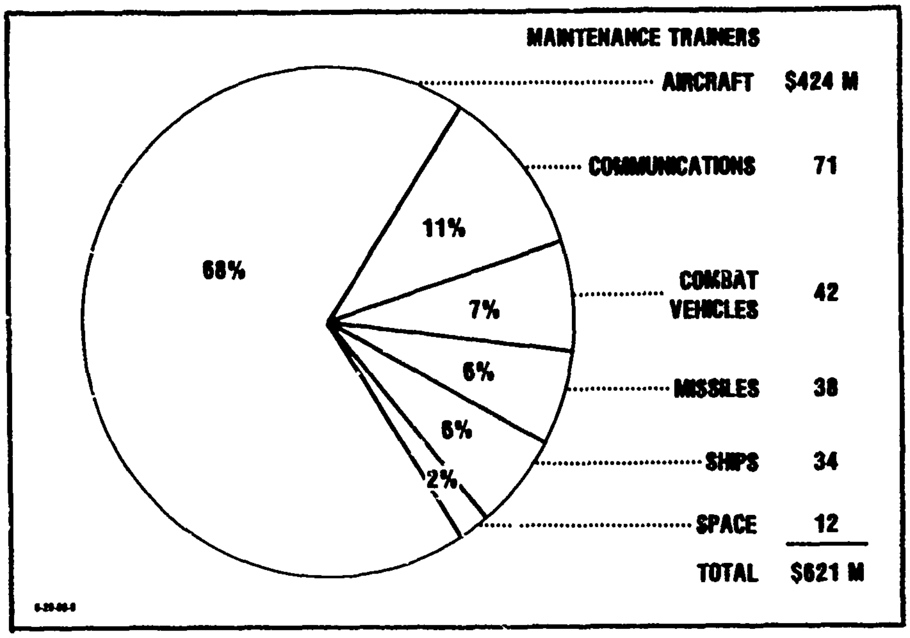


FIGURE 12. Estimated Procurement of Maintenance Trainers (Simulators and Actual Equipment) by the Department of Defense, According to Type of Application, 1977-1985 (Estimated November 1979).

FIGURE 13. Studies on the Effectiveness of Maintenance Simulators, 1967-1930.

SIMULATOR	COURSE	COURSE LENGTH (STANDARD)	COMPARISONS, SIMULATOR TO ACTUAL EQUIPMENT							REFERENCE
			NO. OF SUBJECTS(3)	EFFECTIVENESS(1)				ATTITUDE TO SIMULATORS(2)		
				POORER	SAME	BETTER	TIME SAVINGS	STUDENTS	INSTR.	
Generalized Sonar Maintenance Trainer	Sonar maintenance (special course)	4 days(3)	9		•		22%(4)	Students favorable		Parker and DePauli, 1967
	Intermediate General Electronics	4 weeks	20		•					DePauli and Parker, 1969
EC II	APQ-126 Radar		17					+		Spangenburg, 1974
	Mohawk Propeller System	3 hrs	33			•				Borst, 1974
	Hydraulic and Flight Control	32 hrs	13		•	•		+	−	Wright and Campbell, 1975
	Engine, Power Plants and Fuel	24 hrs	13	•	•			+	−	Wright and Campbell, 1975
	Environmental/Utility System	32 hrs	9		••			+	--	Wright and Campbell, 1975
	APQ-126 Radar	60 hrs	15		••			0/+	0/+	McBurk, Pieper, and Miller, 1975
										Platt, 1976
								+	+	Moraner, 1975
	Pilot Familiarization, T-2C	10 hrs	6						+	Moraner, 1976
	Flight Officer Familiarization, TA-4C	11 hrs	30						+	Moraner, 1976
Automated Electronics Maintenance Trainer	FM Tuner									Modrick, Kanarick, Daniel, and Gardner, 1975
	Power Control for ALM-64 Test Equip									Modrick, Kanarick, Daniel, and Gardner, 1975
	ALM-100 Test Set									Modrick, Kanarick, Daniel, and Gardner, 1975
	Visual Target-Acquisition System									Modrick, Kanarick, Daniel, and Gardner, 1975
Generalized Maintenance Training System	SRC-20 UHF Voice Command System		20				ABOUT 50%	+		Rigney, Towne, King, and Moran, 1978
	SPA-61 Radar Repeater	16 hrs	10					+		Rigney, Towne, Moran, et al., 1978
Fault Identification Simulator	Hagan Automatic Boiler	5 wks	16		•		ABOUT 50%			Sweeny (in Malcolm 1979)
6883 Converter/ Flight Control Systems Test Station	F-111 Avionics Maintenance	9 days(5)	90		•			+	0/+	Cicchinelli, Harmon, Keller and Kottenstette, 1980

(1)Some studies provide more than one comparison.
(2) + favorable, 0 neutral, − negative; 0/+ neutral to mildly favorable
(3)Simulator only.
(4)Average of five maintenance tasks in final test.
(5)Training with 6883 takes 2 days in a 23-week course; 6 days in this special test.

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	SIMULATOR/AET
HIGH ESTIMATE	
RDT&E + 1 UNIT	0.60
LOW ESTIMATE	
RECURRING	0.20

FIGURE 14. High and Low Estimates for the Acquisition Costs of Maintenance Simulators/Actual Equipment Trainers.

AMORTIZATION	
ACQUISITION COST	$595 K
SAVINGS PER YEAR	$160 K

$$\text{AMORTIZATION} = \frac{\$595}{\$160} = 3.7 \text{ YEARS}$$

FIGURE 15. Amortization of the 6883 Test Stand, Three-Dimensional Maintenance Simulator (Source: Cicchinelli, Harmon, Keller and Kottenstette, 1980).

EFFECTIVENESS	FACTOR	SAVINGS OR COST		
		FLIGHT SIMULATORS	COMPUTER-BASED INSTRUCTION	MAINTENANCE SIMULATORS
ABOUT THE SAME	STUDENT TIME	50% OF SIMULATOR TIME	30%	20-50%
	ACQUISITION COST	30-65%	?	20-60%
	OPERATING COST	10%	?	50%
	LIFE-CYCLE COST	65%	?	40%
	AMORTIZATION	2 YEARS	?	4 YEARS

FIGURE 16. Summary of Findings on the Effectiveness and Cost of Flight Simulators, Computer-Based Instruction and Maintenance Simulators.

ance is the more relevant measure of training effectiveness. This observation applies equally to conventional instruction. One exception to these comments is that supervisors' ratings showed about the same job performance for students trained either with the 6883 simulator or actual equipment; however, supervisors' ratings are not objective performance measures. On-the-job performance measures are an inherent aspect of evaluating flight simulator because all students who were trained in simulators were observed later in aircraft in flight, as were obviously those trained only in aircraft. However, measures of student performance in aircraft are based on instructors' ratings on well-developed rating scales rather than on objective measures recorded by instruments. It may well be that, regardless of method of training, performance at school does not predict later performance on the job. Whether there is a high or low degree of relationship between measures taken at school and later on the job is an important question that still remains to be answered for almost all types of training.

A basic premise of innovations to training such as flight simulators, computer-based instruction and maintenance simulators, is that they will improve the quality of instruction and, thus, the effectiveness of training. The basic findings, as reported above, are that these innovations to training are about as effective as the methods they can replace and save appreciable amounts of student time. There have been only a few demonstrations of slight improvements, none large enough to have any practical significance. Overall, this means that these innovations yield improvements in efficiency, i.e., cost, but not in effectiveness.

Innovations to training--based on what we know about these three examples--may have a potential for improved effectiveness, but this has not been conclusively demonstrated. Superior student achievement, compared to that with conventional instruction, was found in about one-third of the studies of computer-assisted instruction (CAI); the amounts of superiority were small. Two such results (out of 13 cases) were reported for the use of maintenance simulators; none for flight simulators. It is often said that maintenance simulators can provide better training because they can demonstrate a larger number of malfunctions than is possible with actual equipment trainers. This plausible claim has not been verified nor, apparently, even tested. Course materials and instructional procedures incorporated in innovations to training have essentially been modeled on the current methods. This imposes an unnecessary limitation on improvements in effectiveness that may well be present. The goal of almost all improvements to training so far examined seems to be equal effectiveness and savings in the cost of training; only lip service has been given to improved effectiveness. It appears possible to produce improvements in effectiveness if costs were kept constant, i.e., if large savings in cost were not also required at the same time.

Finally, there has been no attempt to look for trade-offs between cost and effectiveness. To do so would require different types of comparisons, different experimental designs, and a greater concern with improving training than is currently evident. It would require control (in experiments), over the amount of time students spend with simulators or CAI/CMI to determine the shape of the learning curve and thus the optimum time to go from simulator to the aircraft or actual equipment.

Additional practice in training brings diminishing improvements in performance. The well-known phenomenon of the learning curve and its impact on the cost-effectiveness of training has been almost totally disgregarded except in one excellent study. Povenmire and Roscoe (1973) showed that the transfer effectiveness ratio, which measures the amount of flight time saved due to use of a simulator, continued to decrease and eventually became flat (after about 7 hours in this particular study where the task was for the pilot to qualify in a check flight). When the decreasing TERs were compared to the costs of using the simulator or aircraft in this case, it became clear that it would be more cost-effective to use the airplane rather than the simulator for additional training after about 4 hours in the simulator (and not after 7 or 11 hours, as was done for some of the test groups in this study).

A concern with trade-offs between cost and effectiveness would also require us, in effect, to develop simulators that differ in complexity, and therefore in cost, to see the extent to which effectiveness may change as a consequence of changes in the cost of equipment. Up to the present, all comparisons have been made with a simulator designed, more or less to an arbitrary level of complexity, as the result both of the Instructional System Design process and of negotiations between operators, trainers, and developers over requirements and costs. This process needs data on the critical relationship between cost and effectiveness in order to make optimum trade-offs.

CONCLUSIONS

Flight simulators, computer-based instruction and maintenance training simulators appear to be as effective as the methods of training they can replace; they also can reduce the costs of training. Thus, they appear to be cost-effective compared to more conventional methods of training. These new methods of training have not been demonstrated to be more effective than the older ones, although it is possible, if cost savings were not required or were kept constant, that they

might be. Trade-offs between the effectiveness and cost of alternative training systems have not been performed. To do so, more reliable and more complete data on effectiveness and cost would be required in most areas of training.

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